

BELLCOMM, INC.

1100 SEVENTEENTH STREET, N.W. WASHINGTON, D.C. 20036

COVER SHEET FOR TECHNICAL MEMORANDUM

TITLE- Lunar Orbiter III  
Exposure Determination

TM- 67-1012-9

DATE- August 9, 1967

FILING CASE NO(S)- 340

AUTHOR(S)- H. W. Radin

FILING SUBJECT(S)- Lunar Orbiter  
(ASSIGNED BY AUTHOR(S)- Calibration  
Data Analysis

ABSTRACT

During Lunar Orbiter Mission III, a real-time evaluation was made of spacecraft photographic exposures, in order to correct the shutter settings for subsequent pictures. The high resolution (HR) pictures were under-exposed, relative to predictions, by a factor of about 0.7 (half an f-stop); early in the mission this empirical "exposure factor" was incorporated into subsequent exposure predictions, and properly exposed photos resulted. Also, the Mission III exposure factor was used for the early Mission IV photos, and proved to be quite close to the proper value.

The exposure difference between the HR and MR pictures, obtained early in the program, has been virtually eliminated by the use of a neutral density filter on the MR camera.

(NASA-CR-88331) LUNAR ORBITER III EXPOSURE  
DETERMINATION (Bellcomm, Inc.) 21 p

N79-72888

Unclas

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CR-88331  
(NASA CR OR TMX OR AD NUMBER)

14  
(CATEGORY)

BA-145A (3-67)

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**BELLCOMM. INC.**

1100 Seventeenth Street, N.W. Washington, D. C. 20036

SUBJECT: Lunar Orbiter III Exposure  
Determination - Case 340

DATE: August 9, 1967

FROM: H. W. Radin

TM-67-1012-9

TECHNICAL MEMORANDUM

1.0 INTRODUCTION

During Lunar Orbiter Mission III, a real-time evaluation was made of the spacecraft photographic exposures, in order to influence the shutter settings for subsequent pictures. The method used was a measurement of the received spacecraft signals, before reconstruction into photographs.<sup>(1)</sup>

The high resolution (HR) and moderate resolution (MR) pictures were about equal in exposure, in contrast to Orbiters I and II; however, the log exposures averaged about 0.15 less than the predicted values.

2.0 MEASURING TECHNIQUE

The method used follows closely the one used for postmission exposure evaluation for Orbiters I<sup>(1)</sup> and II; the detected video signal was connected to an operational amplifier having an RC circuit in the feedback loop, and the resulting integrated video was displayed on a chart recorder. A hold circuit was incorporated to avoid averaging-in the unexposed framelet ends.

A portion of a chart is shown in Figure 1; the upper trace was produced with a simple RC filter (0.1 sec time constant), and the lower trace with the operational amplifier and hold circuit (10 sec time constant).

In order to compute the average exposure of a frame, the voltages at the centers of the center three framelets were averaged (using the lower trace) and converted to log exposure.

3.0 CALIBRATION DATA

The procedure for developing the spacecraft calibration curves has already been described in some detail<sup>(1)</sup>, and only a brief summary will be given here.

### 3.1 D vs. LOG E CURVE

Prior to launch, a piece of flight film is exposed to a step wedge, bimat-developed, and measured on a visual (diffuse) densitometer. The data<sup>(2)</sup> are given in Table 1. After the measurements are made, the three exposures are cut apart; one is sent to NASA/LRC, another to Boeing in Seattle, and the third is retained at ETR.

The exposure sent to Seattle was measured again by R. E. Douglass<sup>(3)</sup> on a visual densitometer. An Ansco Model 4 microdensitometer was calibrated against the visual densitometer, and was then used to measure the edge print gray scale densities.

Periodically, Eastman Kodak publishes nominal density data for its films; the latest such nominal SO-243 data for bimat development (not specific to Orbiter III) are shown in Table 2.

The three sets of data are plotted in Figure 2. The difference between the Northrup (ETR) and Douglass (Seattle) curves are probably due primarily to differences in the densitometers used.

The above curves are all plotted in terms of ASA visual (diffuse) density, while the density specific to the Orbiter is readout density; accordingly, Douglass' curve has been converted to readout density,<sup>(4)</sup> and the converted curve appears in Figure 3. The curve in Figure 3 was used for all shutter speed determinations and exposure analyses during Mission III.

### 3.2 EDGE PRINT DATA

The gray scale log exposures for Orbiter III flight film were published by Eastman Kodak<sup>(5)</sup>; the values are listed in Table 3. These values were obtained by measuring the densities of the gray scale steps and reading the exposures from a flight-specific D-log E curve measured at EK.

A separate determination of gray scale densities was made by R. E. Douglass; and was published<sup>(3)</sup> with his film curve; these appear in Table 4.

Both sets of gray scale data have been plotted on the Douglass D-log E curve, and appear in Figure 4.

In addition to the gray scales, there is a relatively large area in the edge print, with narrow diagonal lines passing through it, called the "background density" or "focus stop" region. The exposure of this area is well controlled, and is made equal to the exposure of the second step of the edge print gray scale (the next-to-the-least-dense step).

This region is used to set the spacecraft video gain before each readout sequence. Whatever the actual developed density of this region, the gain is set to transmit 5 volts when the optical-mechanical scanner is stopped in this region (Figure 1).

### 3.3 V-T AND V-LOG E CURVES

As in Reference 1, we may assume the transmitted voltage vs. film transmission characteristic to be linear-- then the background density yields a particularly simple way to obtain the V-T curve. The value of transmission corresponding to background density is  $T = 10^{-D}$ ; to get the V-T curve we simply plot this value\* opposite 5 volts and draw a straight line to the origin. This curve is plotted as Figure 5.

To obtain the V-LOG E curve, enter the V-T curve with a value of voltage, convert the corresponding value of T to readout density ( $D = \log \frac{1}{T}$ ), and find log exposure from the D-LOG E curve. Figure 6 is the result.

### 4.0 SUMMARY OF RESULTS

Exposure and density measurements for a number of HR and MR frames are listed in Table 5, and a comparison with predictions in Table 6. The  $\Delta Q$  and  $\Delta M$  values in Table 6 refer to the differences between the measured values and the predictions obtained from the QUAL program and the mission advisors, respectively. The data used in these predictions (or the sources) are listed in Table 7.

---

\*For Mission III, the readout density of step 2 was 0.3 (Figure 4), leading to a value of 0.5 for T.

The mean value of  $\Delta Q$  is -0.142, and the mean of  $\Delta M$  is -0.162, both in log exposure units. This corresponds to underexposure by a factor of about 0.7.

## 5.0 DISCUSSION

It can be seen from Table 5 that the discrepancy between HR and MR exposures obtained on Lunar Orbiter I has been virtually eliminated, although there remains an underexposure relative to predictions of about a factor of 0.7; approximately the same factor was obtained during Mission IV. The cause of this underexposure is presently unknown.



1012-HWR-hjt

H. W. Radin

Attachments:

References

Tables 1 - 7

Figures 1 - 6

BELLCOMM, INC.

REFERENCES

1. Lunar Orbiter I Exposure Determination, Bellcomm TM-67-1012-2, H. W. Radin, February 15, 1967
2. These data were obtained from R. Northrup of the Boeing Company
3. Gray Scale Calibration of Flight Film for PS5/SC6, Memorandum No.2-7821-10-63, February 3, 1967, from R. E. Douglass to R. G. Erwood and W. P. Williams
4. Densitometry Relationships Utilized in LOP Film Evaluation, LOP Engineering Note L-022992-KU, October 7, 1966; S. Heinmiller
5. Memorandum L-024248, from Hansell of Eastman Kodak to Conderacci of Boeing



TABLE I  
FLIGHT CERTIFICATION TEST - ORBITER III

STEP #	LOG EXPOSURE	VISUAL DENSITY EXP #1	VISUAL DENSITY EXP #2	VISUAL DENSITY EXP #3	AVERAGE DENSITY
BASE+FOG					0.40
1	2.73	0.43	0.42	0.44	0.43
2	2.90	0.47	0.46	0.48	0.47
3	1.04	0.56	0.54	0.56	0.55
4	1.24	0.74	0.72	0.72	0.73
5	1.38	0.90	0.90	0.92	0.91
6	1.54	1.11	1.10	1.12	1.11
7	1.72	1.34	1.32	1.38	1.35
8	1.84	1.53	1.51	1.55	1.53
9	0	1.73	1.70	1.76	1.73
10	0.17	1.94	1.89	1.95	1.93
11	0.33	2.10	2.07	2.12	2.10
12	0.47	2.24	2.20	2.25	2.23
13	0.61	2.35	2.31	2.36	2.34
14	0.74	2.43	2.38	2.44	2.42
15	0.89	2.49	2.45	2.50	2.48
16	1.03	2.54	2.50	2.53	2.52
17	1.19	2.58	2.53	2.58	2.56
18	1.33	2.60	2.58	2.62	2.60
19	1.46	2.63	2.60	2.63	2.62
20	1.60	2.65	2.63	2.64	2.64
21	1.74	2.67	2.65	2.66	2.66

	↑	↑	↑
PRESENT LOCATION }	ETR	TBC/SEATTLE	NASA/LRC

THE ABOVE DENSITIES WERE OBTAINED ON THE DENSITOMETER AT ETR BY R. NORTHRUP, AND INCLUDE SENSITOMETER & DENSITOMETER CORRECTIONS. THE MEASUREMENTS BY R. DOUGLASS ARE ON EXP. #2 ONLY, NOW AT SEATTLE.

TABLE 2  
LATEST E.K. NOMINAL SO-243 H & D DATA

LOG E	VISUAL DENSITY
$\overline{2.65}$	0.40
$\overline{2.85}$	0.44
$\overline{1.05}$	0.53
$\overline{1.25}$	0.67
$\overline{1.45}$	0.87
$\overline{1.65}$	1.10
$\overline{1.85}$	1.38
0.05	1.67
0.25	1.96
0.45	2.22
0.65	2.42
0.85	2.58

DATA SUPPLIED BY G.C. BROOME, NASA/LRC,  
2/6/67

TABLE 3  
ORBITER III EDGE PRINT GRAY SCALE EXPOSURES

STEP NO.	LOG E
1	$\overline{2.41}$
2	$\overline{2.60}$
3	$\overline{2.75}$
4	$\overline{2.85}$
5	$\overline{1.05}$
6	$\overline{1.25}$
7	$\overline{1.46}$
8	$\overline{1.66}$
9	$\overline{1.83}$

LOG EXPOSURE ERROR:

FLASH-TO-FLASH VARIATION  $\pm 0.02$

TOTAL VARIATION  $\pm 0.05$

THE ABOVE DATA (FOR PS-5) ARE CONTAINED IN  
DOCUMENT L-024248, A MEMORANDUM TO THE BOEING CO.  
FROM J.R. HANSELL OF EASTMAN KODAK.

TABLE 4  
ORBITER III EDGE PRINT GRAY SCALE DENSITIES

STEP NO.	VISUAL DENSITY
1	0.36
2	0.37
3	0.39
4	0.42
5	0.49
6	0.65
7	0.87
8	1.17
9	1.45

THE ABOVE DATA WERE MEASURED FROM FLIGHT  
CERTIFICATION LEADER EXPOSURE #2, BY  
R.E. DOUGLASS, AT SEATTLE. THEY ARE CONTAINED  
IN MEMORANDUM #2-7821-10-63 FROM DOUGLASS TO  
R.G. ERWOOD/W.P. WILLIAMS, DATED FEB. 3, 1967.

TABLE 5  
LUNAR ORBITER III - MEASURED EXPOSURES

READOUT SEQUENCE	SITE	FRAME NUMBER	LOG EXPOSURE		READOUT DENSITY	
005	P-1	H-12	$\overline{1.21}$		0.61	
		M-11		$\overline{1.25}$		0.66
006		H-14	$\overline{1.19}$		0.60	
		M-13		$\overline{1.24}$		0.65
007		H-16	$\overline{1.16}$		0.56	
		M-15		$\overline{1.27}$		0.68
014	P-3	H-40	$\overline{1.10}$		0.51	
019	P-5a	H-54	$\overline{1.03}$		0.46	
020		M-58		$\overline{2.86}$		0.37
	P-5b	H-60	$\overline{1.05}$		0.47	
021		H-62	$\overline{1.01}$		0.44	
		M-60		$\overline{1.05}$		0.47
026	S-7	H-75 <sup>a</sup>	$\overline{1.00}$		0.44	
	S-6	M-73		$\overline{2.97}$		0.42
028	S-10	H-83	$\overline{1.41}$		0.87	
		M-81		$\overline{1.36}$		0.80
029	P-7a	H-87	$\overline{1.19}$		0.60	
033		H-98	$\overline{1.25}$		0.66	
	P-7b	M-96		$\overline{1.30}$		0.72
034		H-100	$\overline{1.27}$		0.69	
035		M-100		$\overline{1.29}$		0.71
	S-14	H-102	$\overline{2.88}$		0.38	
036		M-102 <sup>b</sup>		$\overline{2.93}$		0.40
	S-15	H-104 <sup>c</sup>	$\overline{1.38}$		0.83	
040	P-8	H-124 <sup>d</sup>	$\overline{1.33}$		0.76	
	S-22	M-122		$\overline{1.27}$		0.68
	S-20	H-123 <sup>b</sup>	$\overline{1.24}$		0.65	
042	P-8	H-131 <sup>d</sup>	$\overline{1.42}$		0.88	

a - WIDE SIGNAL FLUCTUATIONS

b - OFF CENTER OF FRAME

c - WHITE LEVEL SHIFT

d - THERE IS AN ALBEDO VARIATION IN THE PROPER DIRECTION TO SUGGEST THIS DENSITY VARIATION.

TABLE 6  
PREDICTED AND MEASURED EXPOSURES

SITE	QUAL PREDICT	MISSION ADVISER PREDICT	MEASURED EXPOSURE	$\Delta Q$	$\Delta M$
P-1	1.36	1.36	1.19	-0.17	-0.17
P-3	1.22		1.10	-0.12	
P-5a	1.16	1.22	1.03	-0.13	-0.19
P-5b	1.16	1.17	1.03	-0.13	-0.14
S-6	1.09	1.09	2.97(M)	-0.12	-0.12
S-7	1.28	1.28	1.00	-0.28	-0.28
S-10	1.44	1.43	1.41	-0.03	-0.02
P-7a	1.47	1.46	1.19	-0.28	-0.27
P-7b	1.38	1.40	1.26	-0.12	-0.14
S-14		1.19	2.88		-0.31
S-15	1.46	1.47	1.38	-0.08	-0.09
P-8	1.48	1.43	1.38	-0.10	-0.05
S-20	1.37	1.45	1.24	-0.13	-0.21
S-22	1.43	1.39	1.27(M)	-0.16	-0.12

NOTE: THE ABOVE MEASURED EXPOSURES ARE AVERAGES OF THE HIGH RESOLUTION FRAMES LISTED IN TABLE 5, EXCEPT WHERE (M) DENOTES A MODERATE RESOLUTION FRAME.

TABLE 7  
SOURCE DATA FOR EXPOSURE PREDICTIONS

ALBEDO: UNITED STATES GEOLOGICAL SURVEY 1:5,000,000  
ALBEDO CHART, ROBERT L. WILDEY & HOWARD A. POHN,  
1967 (TO BE PUBLISHED)

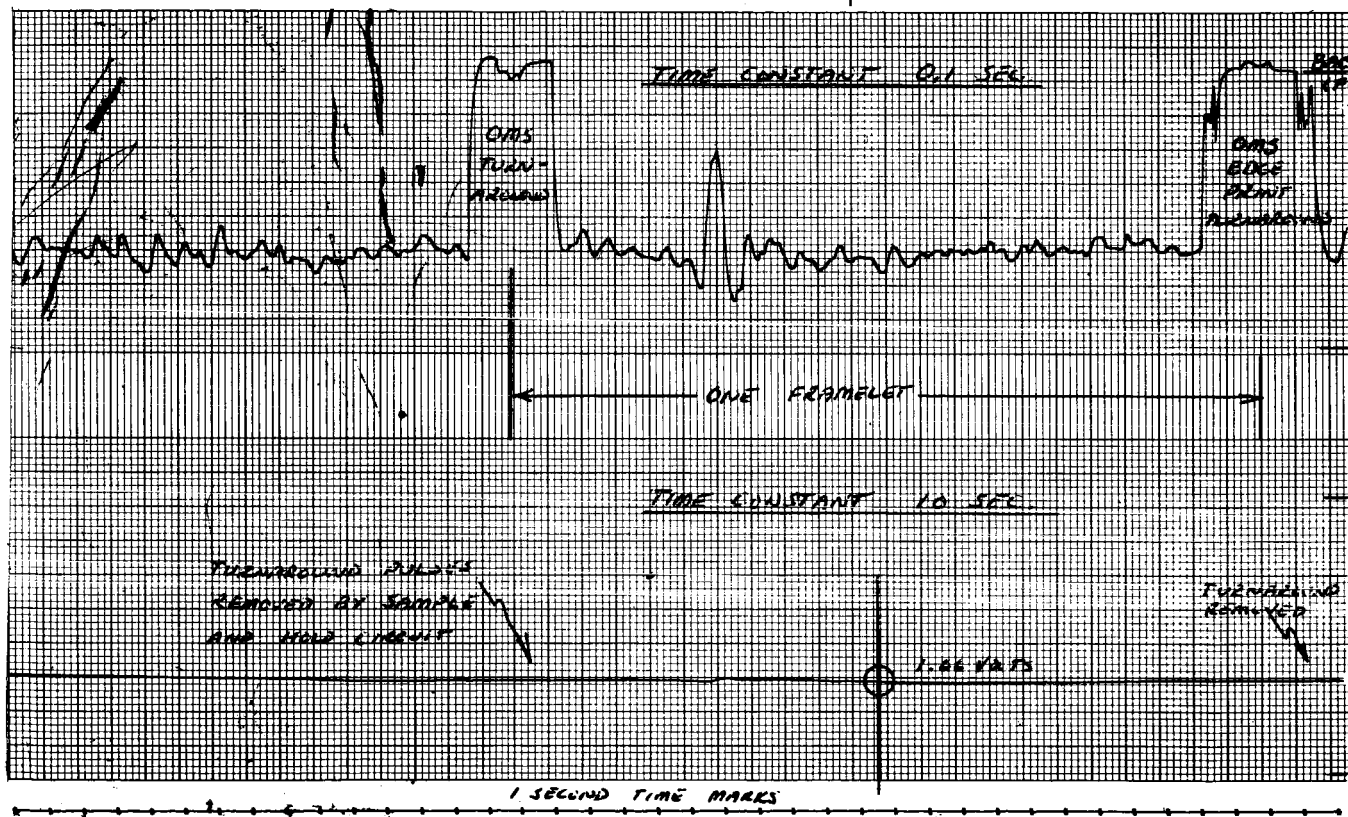
PHOTOMETRIC FUNCTION: NASA-LRC/BOEING PHOTOMETRIC FUNCTION,  
AVAILABLE FROM THE LUNAR ORBITER  
PROJECT OFFICE

LENS TRANSMITTANCES: ON AXIS, WHITE LIGHT SOURCE  
HR (24") LENS: 0.65  
MR (80MM) LENS: 0.59 (INCLUDING NEUTRAL  
DENSITY FILTER)

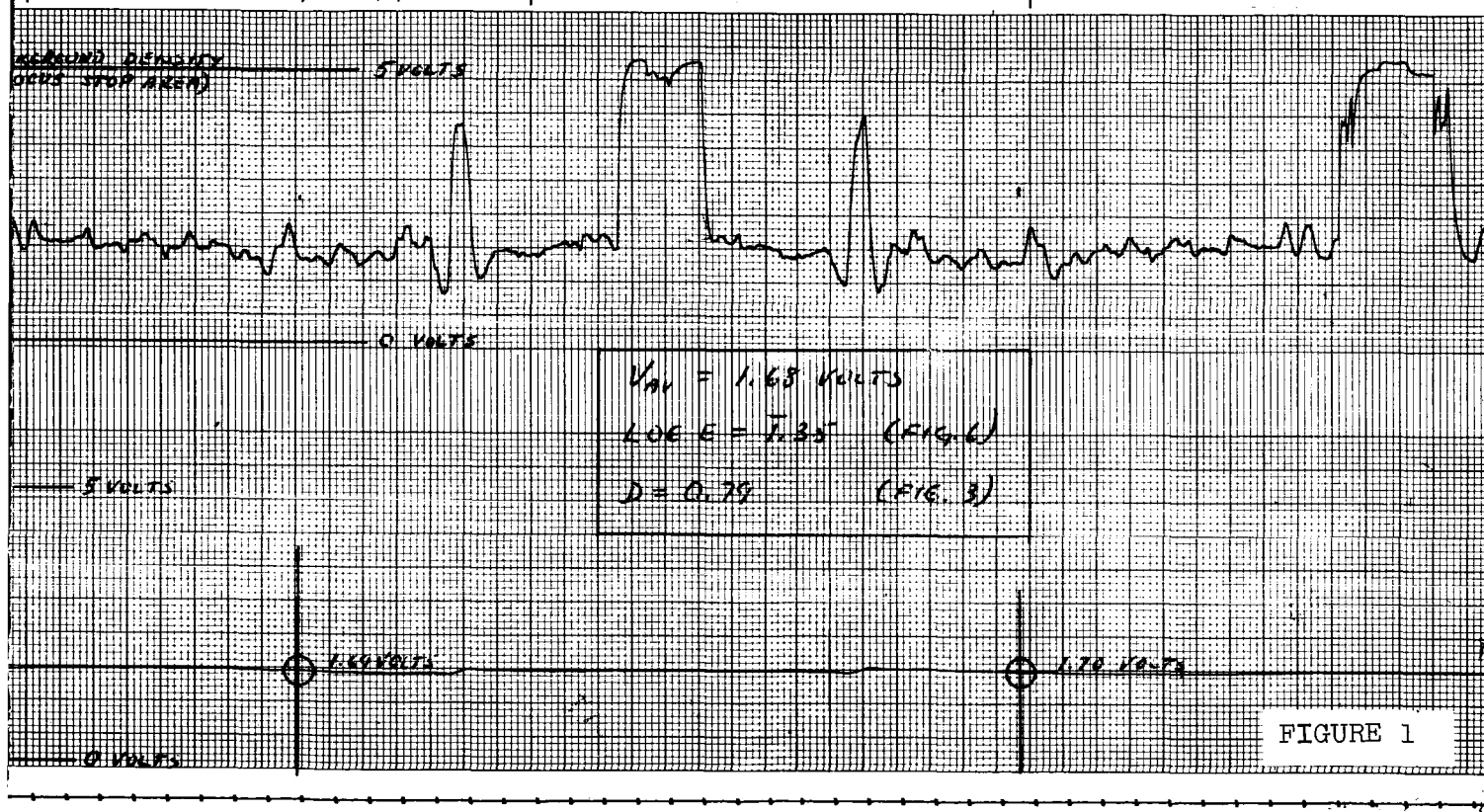
SHUTTER SPEEDS: HR SHUTTER:

NOMINAL	ACTUAL
0.040 SEC	0.0356 SEC
0.020	0.0186
0.010	0.0092

MR SHUTTER APPROXIMATELY NOMINAL







# LUNAR ORBITER III

VISUAL DENSITY vs. LOG EXPOSURE

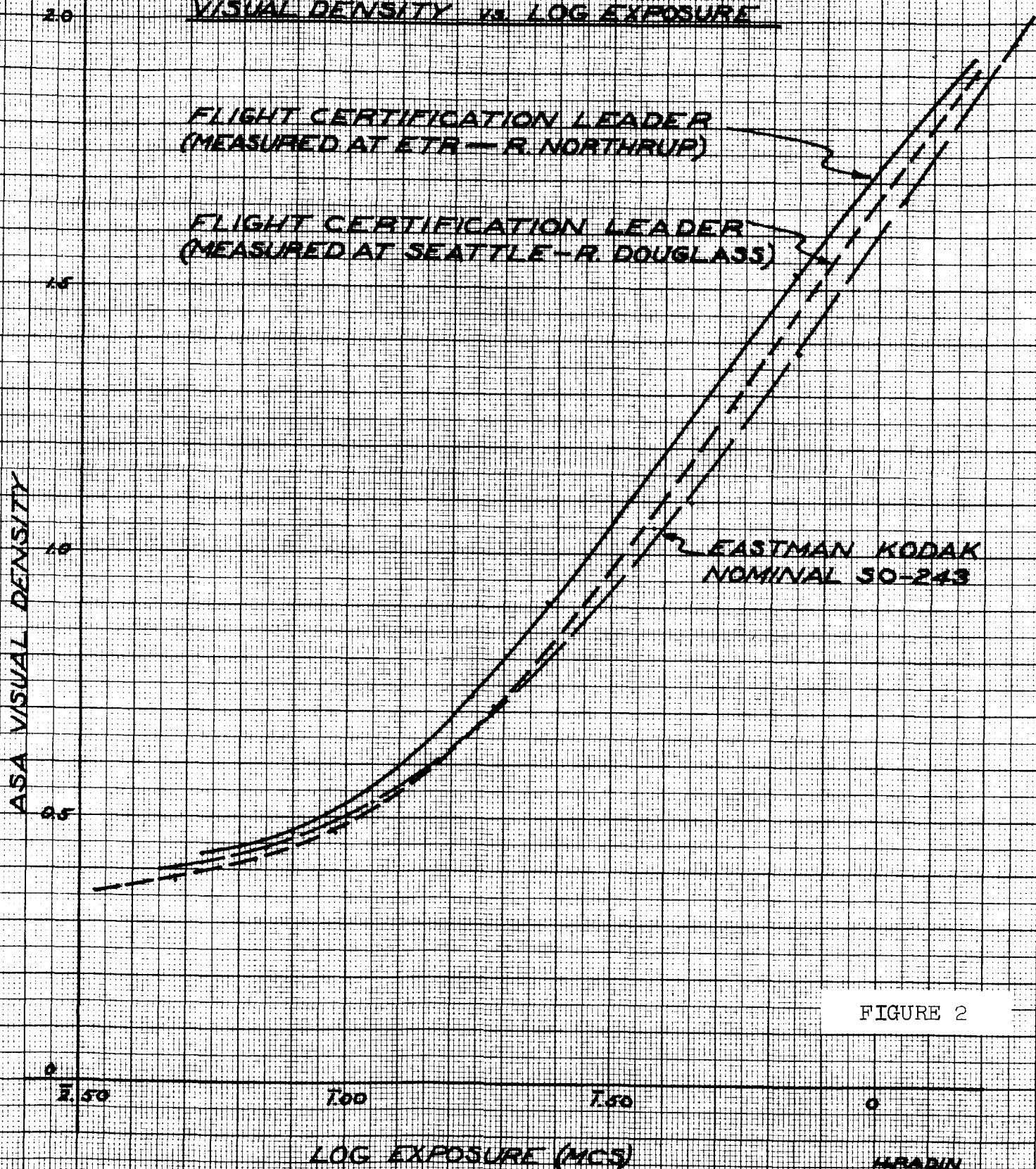


FIGURE 2

HRADIN  
2-7-67

# ORBITER III

## READOUT DENSITY vs. LOG EXPOSURE

VISUAL DENSITY CURVE FROM FLIGHT  
CERTIFICATION LEADER (R.E. DOUGLASS)  
CONVERSION TO READOUT DENSITIES  
BY FIG. II, L-O22992-KU (S. HEINMILLER)

READOUT DENSITY

2.0

1.5

1.0

0.5

2.50

7.00

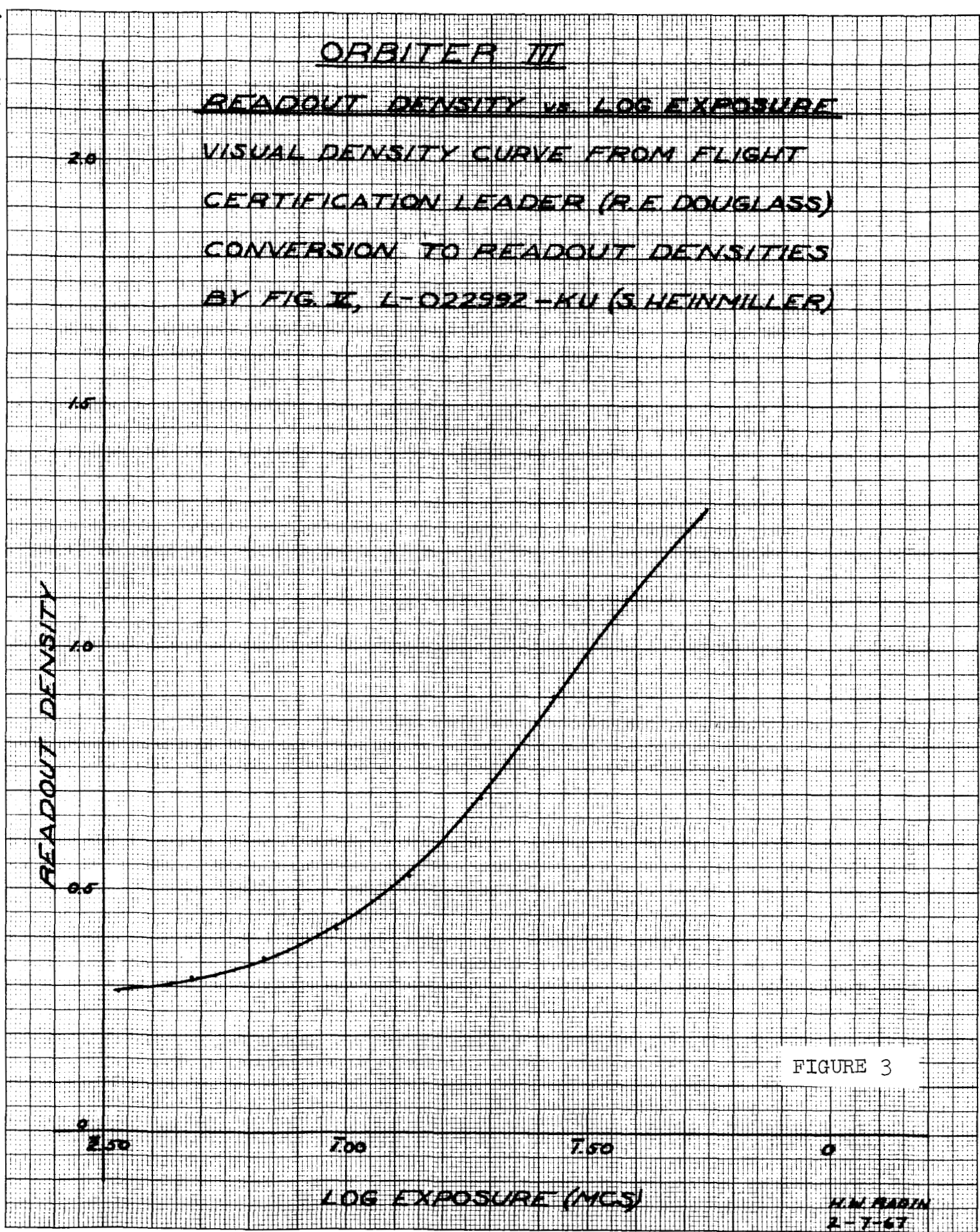
7.50

0

LOG EXPOSURE (MCS)

FIGURE 3

H.W. MARTIN  
2-7-67





# ORBITER III

## READOUT DENSITY vs. LOG EXPOSURE

VISUAL DENSITY CURVE FROM FLIGHT  
CERTIFICATION LEADER (R.E. DOUGLASS)  
CONVERSION TO READOUT DENSITIES  
BY FIG. IV, L-022992-KU (S. HEINMILLER)

GRAY SCALE EXPOSURES:

— DOUGLASS

--- EASTMAN KODAK

READOUT DENSITY

2.0

1.5

1.0

0.5

0

2.50

7.00

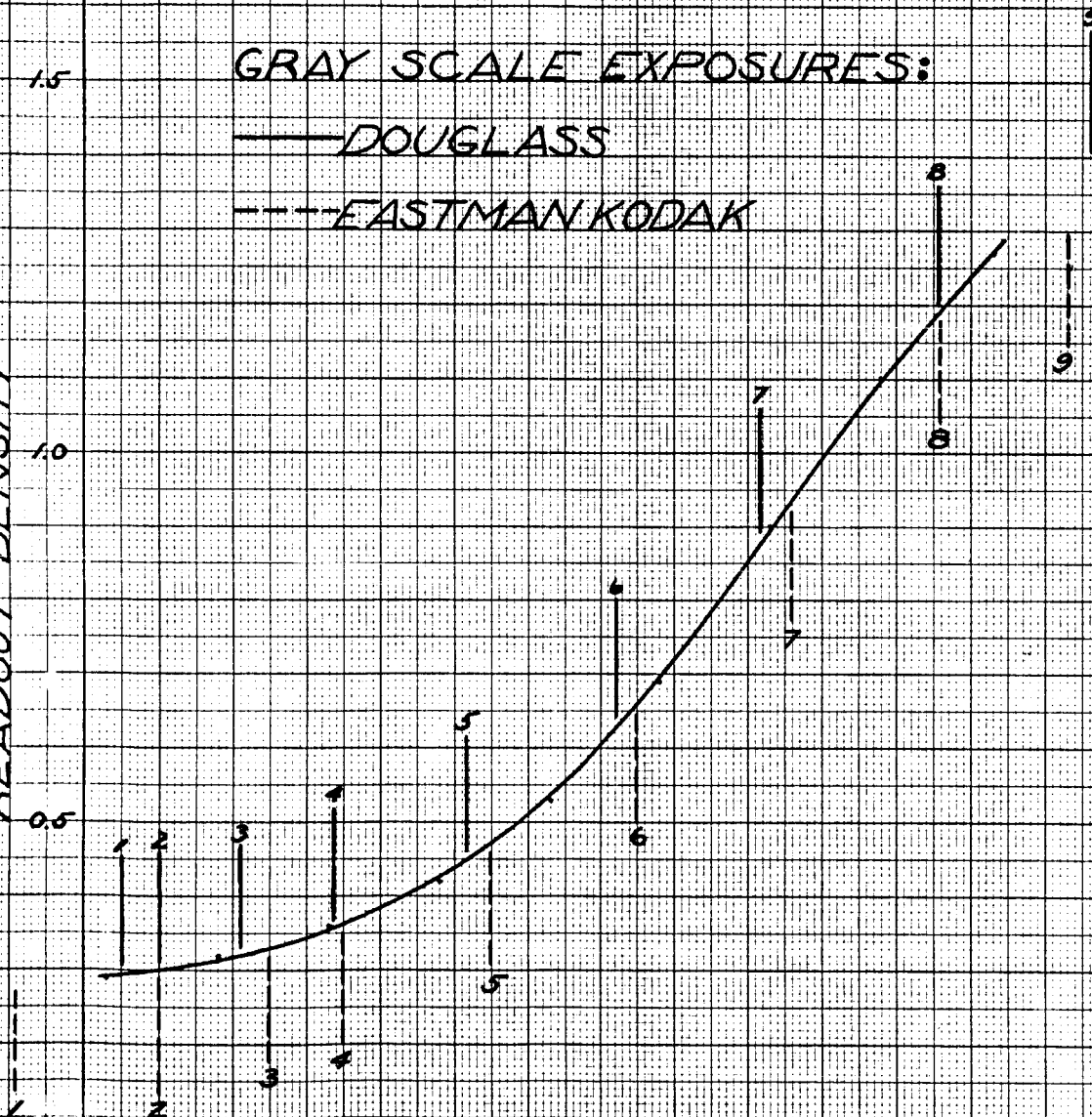
7.50

0

LOG EXPOSURE (MCS)

FIGURE 4

H.W. RADIN  
2-7-67



# ORBITER III

## TRANSMITTED VOLTAGE vs READOUT TRANSMISSION

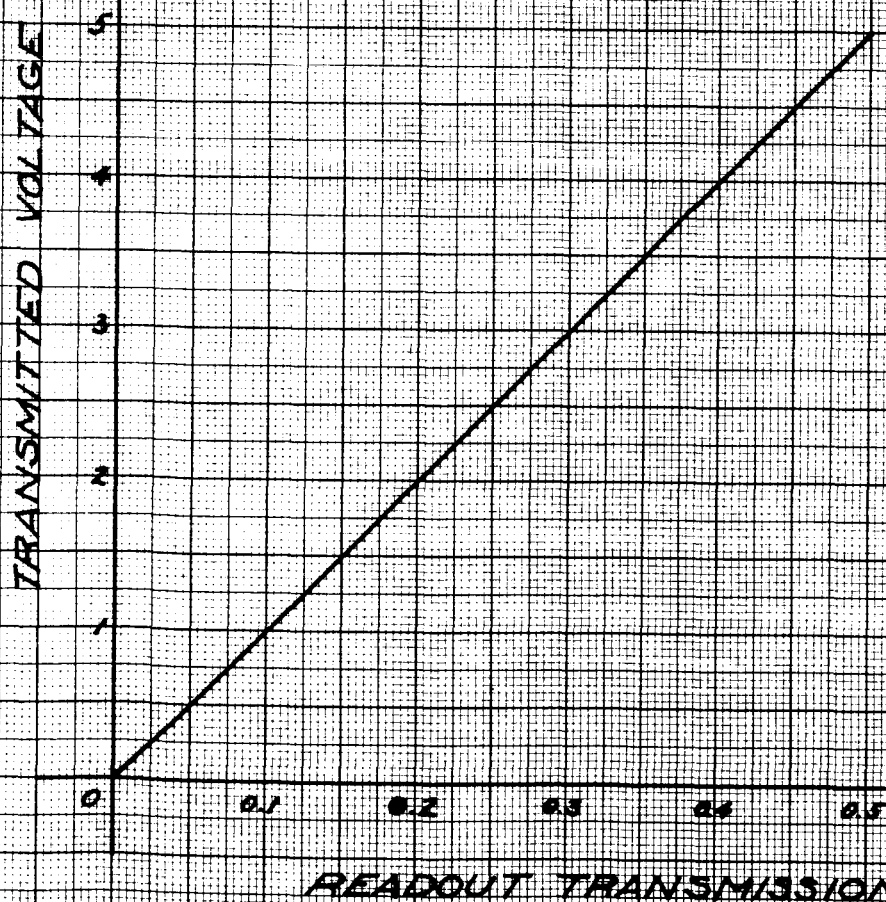


FIGURE 5

# ORBITER III

## TRANSMITTED VOLTAGE vs. LOG EXPOSURE

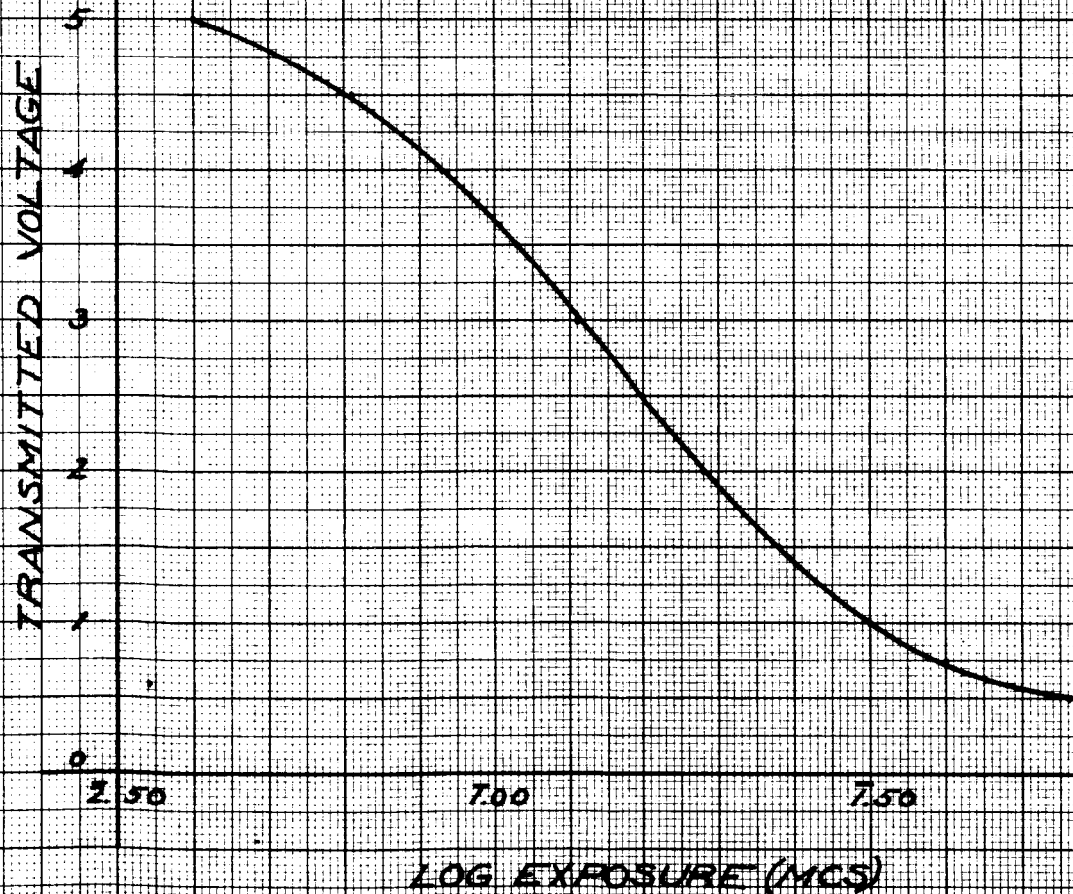


FIGURE 6